Tax Mandates and Factor Input Use: Theory and Evidence from Italy

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1 Introduction

The late 2000s saw such a dramatic deterioration of the budgets of local governments across Europe as to raise doubts about the success of announced fiscal austerity and international rescue programs (European Central Bank, 2011; Lojsch, Rodriguez-Vives and Slavik, 2011). Amongst Southern European countries, the sudden worsening of Portugal's budget figures towards the end of 2011 was partly due to the emergence of extensive local government financial distress, with the small island of Madeira alone disclosing a spectacular debt of over €6 billion.[1] In Spain, regional governments had their debts almost doubled during the financial crisis, with large autonomous communities like Catalonia systematically overshooting their deficit targets and forcing central government to impose quarterly budget reporting.[2]

In Italy, economic growth slowdown and nationwide fiscal consolidation policies posed a threat on the sustainability of regional governments' finances. In spite of the profound reforms of the regional revenue raising structure that took place between the late 1990s and the early 2000s, the terms of the financial relationship between the state and the regions remained opaque, deepening the soft budget constraint problem and generating unprecedented deficit figures in the subsequent years. The release, after the 2005 nationwide regional elections, of sensational data on the debt accumulated over the latest terms of office in a number of regions led the state to mandate increases in regional own tax rates in order to have the burden of debt recovery fall onto those regions' taxpayers. In particular, the regional business income tax rate - an origin based net income-type value added tax on all business activities - increased by state command by one percentage point in deficit-running regions in 2007, with further mandated rate increases following into the regions that were not complying with the agreed upon fiscal consolidation plans.

The objective of this paper is to investigate the effects of such centrally mandated local tax increases on the use of factor inputs in local production processes. I first model factor input use within a multi-jurisdiction neoclassical model, where, as in Cooley, Hansen and Prescott (1995), the aggregate production function in each of a number of localities exhibits constant returns to scale in plant locations, physical capital, and labor, and where physical capital requires energy in fixed proportions depending on the size of energy-saving capital that is installed along with physical capital (Diaz, Puch and Guillo, 2004). Energy-saving capital can either be interpreted as tangible IT (information technology) equipment directly reducing the energy required to produce a final good (such as computer-aided technologies and industrial process electronic control devices), or, more generally, as intangible assets including knowledge, organizational structure, and process design skills (Brynjolfsson, Hitt and Yang, 2002). As in conventional energy use models, physical capital is assumed to be a quasi-fixed factor moving slowly over time in response to input price changes, while energy-saving capital smoothly responds to shocks (Bresnahan, Brynjolfsson

[1] "Portugal dealt blow over budget goal," *Financial Times*, October 4, 2011.
[2] "Hidden debt raises Spain bond fears," *Financial Times*, May 16, 2011.

and Hitt, 2002). By incorporating a multi-level tax structure, where the upper level (state) authority collects corporate income tax revenues and lower-level authorities (regions and localities) levy a business income tax and an excise tax on business energy use respectively, the model predicts that the regional business income tax negatively affects both forms of capital as well as the use of energy in the long run. However, energy and energy-saving capital turn out to be Allen substitutes in the short run. As for the price of energy, the local energy tax lowers the long run equilibrium levels of physical capital and energy - a conventional result in energy use models (Atkeson and Kehoe, 1999) - while its impact on energy-saving capital is ambiguous. In the short run, an higher energy price raises energy-saving capital's productivity and reduces aggregate energy use.

In order to identify the effect of factor input taxes on their use empirically, I exploit the regional business income tax rate increases that were mandated by the state in the Italian regions with excessive public debt. The empirical strategy relies on the abrupt change in central government policy towards regions that accompanied the widespread government changes that occurred at the 2005 regional elections, making the tax mandates exogenous with respect to the evolution of economic conditions, and in particular with respect to shocks to energy use that might hit the regions during the second half of the 2000s. In addition, I control for the fact that provincial authorities directly tax energy by setting an excise tax on all business electricity uses, with the sole exemption of massive energy-intensive establishments. The estimation results based on panel data over a decade (2000-2010) reveal that while mandated business income tax hikes had no effect on regional gross domestic product, they had a significant detrimental impact on employment, and particularly on the use of human resources in S&T (science and technology) occupations, the latter being interpretable as a proxy for energy-saving capital. Moreover, it turns out that regional business income tax increases stimulate province-level business energy use, lending support to the hypothesis of short run substitution between energy and energy-saving capital. On the other hand, provincial excise taxes on energy are generally found to lessen business consumption of energy. Finally, the estimation of region-level and province-level equations augmented with spatially weighted averages of neighboring regions and provinces' business and energy taxes respectively does not provide any evidence of major shifts of production facilities or variable input use from high-tax to low-tax localities during the period analyzed here.

The rest of the paper is structured as follows. Section **2** models factor input taxation by decentralized authorities and its impact on factor input use. Section **3** illustrates the empirical model and the dataset, section **4** presents the results of the econometric analysis, and section **5** tests for the presence of spatial spillovers. Section **6** concludes.

2 Multi-level taxation and factor input use

2.1 Technology

Business activity is carried out in a finite number of localities (indexed by l) that are grouped into regions (indexed by r). $L_r \geq 1$ is the number of localities in region r. Within each locality, production of a final good x takes place at a fixed number of *ex ante* identical plant locations M_l. Locations in this economy constitute a fixed factor of production, and owners of locations earn positive rents (Cooley, Hansen and Prescott, 1995). In particular, a plant consists of a location, capital installed in it, and a fixed requirement of labor and energy to operate it. Let k_{lr} index the stock of physical capital that is directly employed for productive uses at a plant in locality l in region r. Similarly to Atkeson and Kehoe (1999), physical capital is assumed to require energy in fixed proportions to deliver capital services. However, instead of posing the existence of a continuum of capital goods that embody an exogenously given energy intensity (an intrinsic energy type), the energy efficiency score of a production process is determined here by the size of energy-saving capital that is installed along with productive physical capital (Diaz, Puch and Guillo, 2004). Let h index energy-saving capital having the sole role of improving the energy efficiency of a plant, such as computer-aided technologies and industrial process electronic control devices.[3] At time t, the energy requirement (ε_{lrt}) of the physical capital installed in a plant depends on its energy efficiency according to:

$$\varepsilon_{lrt} \geq \frac{\gamma}{h_{lrt}} k_{lrt} \tag{1}$$

where $\frac{\gamma}{h_{lrt}}$ is the energy requirement per unit of productive capital, and is an inverse function of installed energy-saving capital (h_{lrt}), while $\gamma > 0$ is a technology parameter. Any energy used in excess of $\frac{\gamma}{h_{lrt}} k_{lrt}$ is wasted.

The aggregate production function in locality l is:

$$X_{lrt} = M_l x_{lrt} = \begin{cases} M_l \left[\alpha_l k_{lrt}^{\theta} \eta\right] & \text{if} \quad \varepsilon_{lrt} \geq \frac{\gamma}{h_{lrt}} k_{lrt} \text{ and } \eta_{lrt} \geq \eta \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where $\theta < 1$, and η is the fixed labor requirement, meaning that any labor employed at a plant in excess of η has zero marginal product. α_l differs across localities because of time-invariant locality traits reflecting, say, the quality of institutions or the level of social capital. Aggregate production in locality l exhibits constant returns to scale in physical capital, labor and locations.

2.2 Tax structure

In the multi-tiered structure of government of this economy, the state, the regions and the localities set the following business-related taxes. First, realized

[3] While energy-saving capital can be interpreted as tangible IT equipment directly reducing the energy requirement, it might lend itself to a broad human capital interpretation as discussed in section **4** below.

profits paid as dividends to the location owners are taxed at the nationwide, proportional corporate income tax rate π_t. A precise definition of the corporate income tax base is given below. Regional governments set a net income-type value added tax on business income, *i.e.*, a tax on the returns to the two forms of capital net of depreciation, wage payments, and realized profits, at an *ad valorem* rate τ_{rt}. Finally, localities set an excise tax on energy at the rate μ_{lrt}. Energy is elastically supplied to each locality at price v.

Debt interest expenses and labor costs are entirely deductible from the corporate income tax base, but neither is from the regional business income tax base. Depreciation allowances can be deducted from the tax base at the homogeneous rate δ_0 for both taxes. Profits in locality l's establishments (p_{lrt}) can consequently be expressed as:

$$\begin{aligned} p_{lrt} = & \left[x_{lrt} - (v + \mu_{lrt}) \frac{\gamma k_{lrt}}{h_{lrt}} - c_{lrt} \right] (1 - \pi_t - \tau_{rt}) \\ & - w\eta(1 - \pi_t) - (k_{lrt} + h_{lrt}) \left[(\iota + \delta) - \pi_t (\iota + \delta_0) - \tau_{rt}\delta_0 \right] \end{aligned} \tag{3}$$

where ι is the real interest rate, and w is the wage rate.[4] c_{lrt} is an idiosyncratic cost shock that is assumed to be deductible from corporate and value added taxes. It is independently and identically distributed across time and across locations, according to a uniform distribution on the $[\underline{c}, \underline{c} + \Delta_c]$ interval, with $\underline{c}, \Delta_c > 0$. c_{lrt} can be interpreted as capturing the cost of intermediate goods, materials, and services needed to produce x at a given plant. Productive and energy-saving capital are assumed to be supplied elastically to each locality, and to depreciate at the same rate $\delta > \delta_0$.[5]

Consider first a non-stochastic environment where $c_{lrt} = c$, a constant, and the two forms of capital smoothly adjust in response to tax policy changes, with energy use moving according to equation (1). Profit maximization at locality l's plants leads to the following first order conditions for k and h:

$$\begin{cases} \theta\alpha_l k_{lrt}^{\theta-1}\eta - v_{lrt}\dfrac{\gamma}{h_{lrt}} = \dfrac{\iota(1-\pi_t)+\delta}{1-\pi_t-\tau_{rt}} \left[1 - \delta_0 \frac{\pi_t+\tau_{rt}}{\iota(1-\pi_t)+\delta}\right] \\[2ex] v_{lrt}\dfrac{\gamma k_{lrt}}{h_{lrt}^2} = \dfrac{\iota(1-\pi_t)+\delta}{1-\pi_t-\tau_{rt}} \left[1 - \delta_0 \frac{\pi_t+\tau_{rt}}{\iota(1-\pi_t)+\delta}\right] \end{cases} \tag{4}$$

where $v_{lrt} = v + \mu_{lrt}$ is the after-tax energy price, and the right hand side of (4) is the conventional user cost of capital.[6]

[4] I abstract here from modelling the household sector, and assume that labor is elastically supplied at the rate w in all localities. In order to focus on the effect of tax policy changes, all pre-tax input prices are taken to be time-invariant.

[5] The supply of capital goods might be upward sloping in the short run in the presence of external costs of adjusting the capital stock (Goolsbee, 1998). However, the hypothesis that I make here of a perfectly elastic supply curve for the two forms of capital is both conventional and plausible in the context of small localities.

[6] By assuming constant prices for productive capital and energy-saving equipment, I can abstract from consideration of capital gains/losses on undepreciated stocks. Moreover, rental rates for physical capital and IT energy-saving equipment are assumed equal (Krusell *et al.*, 2000).

According to the first order condition for productive capital, the net return to an additional unit of physical capital in production is made of its marginal product minus the energy cost that such unit entails given the energy-saving capital that is installed, *i.e.*, the energy requirement per unit of capital $\left(\frac{\gamma}{h_{lrt}}\right)$ times the energy price inclusive of the excise tax (v_{lrt}). Such return is equalized to the user cost of capital consisting of the compensation for lenders (ι), the true economic depreciation rate (δ), the depreciation provision for tax purposes (δ_0), and state and regional tax rates (π_t, τ_{rt}). The first order condition for energy-saving capital equates the marginal energy saving in energy price terms - *i.e.*, the energy consumption that is foregone thanks to an additional unit of h, and that is increasing in the stock of physical capital installed in the plant - to the rental cost of capital.

Consider the factor input use response to tax policy changes. Following an exogenous (mandated) increase in region r's business income tax rate τ_{rt}, the user cost of capital increases. Given that both forms of capital exhibit decreasing returns, productive and energy-saving capital are driven away from region r's plant locations. The Appendix proves the following:

Proposition 1 *If plant energy use is set to* $\varepsilon_{lrt} = \frac{\gamma}{h_{lrt}} k_{lrt}$*, then: (i)* $\frac{dk_{lrt}}{d\tau_{rt}} < 0$*; (ii)* $\frac{dh_{lrt}}{d\tau_{rt}} < 0$*; (iii)* $\frac{d\varepsilon_{lrt}}{d\tau_{rt}} < 0$.

The new equilibrium input mix has lower physical capital, lower energy-saving capital and lower energy use in region r's localities as a result of the business income tax increase. When all factors of production adjust, energy and capital are complements, mimicking the conventional long-run result of neoclassical energy use models (Pindyck and Rotemberg, 1983).

As far as the effects of provincial energy tax policy are concerned, the Appendix proves the following:

Proposition 2 *If plant energy use is set to* $\varepsilon_{lrt} = \frac{\gamma}{h_{lrt}} k_{lrt}$*, then: (i)* $\frac{dk_{lrt}}{d\mu_{lrt}} < 0$*; (ii)* $\frac{dh_{lrt}}{d\mu_{lrt}} > 0$ *if* $\frac{k_{lrt}}{h_{lrt}} > \frac{\theta}{1-\theta}$*; (iii)* $\frac{d\varepsilon_{lrt}}{d\mu_{lrt}} < 0$.

As the price of energy increases as a result of the increase in the provincial excise tax, use of physical capital unambiguously decreases. On the other hand, energy-saving capital might either increase or decrease as a result of the energy tax shock. First, μ raises the marginal product of energy-saving equipment, pushing towards a more intense use of h. Second, h tends to diminish because less physical capital is employed. The final effect on the use of h turns out to depend on the energy intensity of production. At high energy intensity (high $\frac{k_{lrt}}{h_{lrt}}$), the former effect dominates, and the energy price increase stimulates the use of energy-saving capital. The reverse occurs at low energy intensity. Finally, plant-level energy use unambiguously falls in the long run as a result of the energy tax hike.

2.3 Quasi-fixed factors and short run adjustment

Consider now the short run response of factor input use to fiscal perturbations. In conventional energy use models, physical capital is taken to be a quasi-fixed factor moving slowly in response to input price changes, while energy is treated as a flexible input. In Pindyck and Rotemberg (1983) putty-putty model, the presence of capital adjustment costs coupled with the high short run complementarity between energy and capital leads to little short run response of the former to energy price shocks. In the long run, capital adjusts and so does energy, reproducing a similar capital-energy ratio and generating a large cross-sectional negative correlation between energy prices and capital. A considerable degree of short run complementarity between energy and capital is found in putty-clay models too (Atkeson and Kehoe, 1999), where a large variety of types of capital goods are combined with energy in different fixed proportions. The fact that capital goods are designed with a fixed energy intensity and that investment in each type of capital must be nonnegative delivers a low elasticity of energy use to energy price in the short run. In the long run, permanent increases in energy prices alter the mix of capital goods towards less energy-intensive types, with energy use displaying a large own price elasticity. As for energy-saving capital, the arguments spelled out and the evidence reported in Bresnahan, Brynjolfsson and Hitt (2002), Brynjolfsson and Hitt (2000), Brynjolfsson, Hitt and Yang (2002) suggest that it ought to be treated as flexible. Indeed, since IT capital tends to be disproportionately associated with intangible assets relative to ordinary physical capital, firms might sustain non-negligible adjustment costs in terms of software development, business process innovation, and workplace organizational transformation before computer capital becomes fully effective. However, it is well documented by case examples and large-sample empirical evidence that ITs are the easiest to vary of the assets in the cluster of complementary innovations (Bresnahan, Brynjolfsson and Hitt, 2002), and this hypothesis seems plausible in the context of narrowly focused energy-saving technologies.

I allow establishments to be hit by idiosyncratic cost shocks c_{lrt} having the stochastic properties defined above. Within this environment, entrepreneurs' decisions on production across the available plant locations take place in two stages: at the beginning of period t, they have to decide on physical capital installation in a locality. This occurs after observing the tax rate vector $\mathbf{z}'_{lrt} = [\pi_t \; \tau_{rt} \; \mu_{lrt}]$, but before observing the idiosyncratic shocks hitting plants. All other variables, including the size of energy-saving capital employed and the binary choice of whether a plant will actually be operated, are set in the second stage, after observing the realization of c_{lrt}. The second stage decision determines the capacity utilization rate across locality l's plants, with unprofitable plants remaining idle.

Consider the second stage plant operation decision first: upon observing the idiosyncratic shock c_{lrt}, and once k has been installed, plant l is operated if the value of output exceeds variable input costs, *i.e.*, if net operating income (y_{lrt})

is positive:

$$y_{lrt} \equiv (1 - \pi_t - \tau_{rt}) \left(\alpha_l k_{lrt}^{\theta} \eta - v_{lrt} \frac{\gamma k_{lrt}}{h_{lrt}} - c_{lrt} - \eta \lambda_{rt} - h_{lrt} u_{rt} \right) \geq 0 \tag{5}$$

where $\lambda_{rt} \equiv w \left(\frac{1-\pi_t}{1-\pi_t-\tau_{rt}} \right)$ is the tax-adjusted cost of labor, u_{rt} is the user cost of capital in region r, and energy saving capital is set according to:

$$v_{lrt} \frac{\gamma k_{lrt}}{h_{lrt}^2} = u_{rt} \equiv \frac{\iota(1-\pi_t)+\delta}{1-\pi_t-\tau_{rt}} \left[1 - \delta_0 \frac{\pi_t + \tau_{rt}}{\iota(1-\pi_t)+\delta} \right] \tag{6}$$

Let c_{lrt}^* be the cutoff cost shock at which plant l just breaks even:

$$c_{lrt}^* = \alpha_l k_{lrt}^{\theta} \eta - v_{lrt} \frac{\gamma k_{lrt}}{h_{lrt}} - \eta \lambda_{rt} - h_{lrt} u_{rt} \tag{7}$$

Whenever a plant has an higher cost shock than c_{lrt}^*, it will remain idle:

$$x_{lrt} = \begin{cases} \alpha_l k_{lrt}^{\theta} \eta & \text{if } c_{lrt} \leq c_{lrt}^* \\ 0 & \text{if } c_{lrt} > c_{lrt}^* \end{cases} \tag{8}$$

Given that c_{lrt} is uniformly distributed between $\underline{c}$ and $\underline{c} + \Delta_c$, the fraction of plants that are operated in locality l is:

$$\Pr(c_{lrt} < c_{lrt}^*) = \int_{\underline{c}}^{c_{lrt}^*} \frac{1}{\Delta_c} dc_{lrt} = \frac{c_{lrt}^* - \underline{c}}{\Delta_c} \tag{9}$$

Turn now to the first stage decision about installation of physical capital. Expected profits at locality l's establishments are:

$$\begin{aligned} & E\left[p_{lrt} \middle| \mathbf{z}_{lrt}\right] \\ & = E\left[y_{lrt} \middle| \mathbf{z}_{lrt}\right] - k_{lrt}\left[(\iota+\delta) - \pi_t(\iota+\delta_0) - \tau_{rt}\delta_0\right] \\ & = \int_{\underline{c}}^{c_{lrt}^*} \frac{1}{\Delta_c}\left[y_{lrt} \middle| \mathbf{z}_{lrt}\right] dc_{lrt} - k_{lrt}\left[(\iota+\delta) - \pi_t(\iota+\delta_0) - \tau_{rt}\delta_0\right] \end{aligned} \tag{10}$$

Using the fact that $c_{lrt}^* = \Delta_c \Pr(c_{lrt} < c_{lrt}^*) + \underline{c}$ from equation (9), the first order condition for physical capital installation is:

$$\left[\theta \alpha_l k_{lrt}^{\theta-1} \eta - v_{lrt} \frac{\gamma}{h_{lrt}} \right] \left(\frac{c_{lrt}^* - \underline{c}}{\Delta_c} \right) = u_{rt} \tag{11}$$

Equation (11) has a straightforward interpretation: the marginal return of physical capital weighted by the probability that the plant will be operated equals the user cost of capital. With physical capital determined according to (11), expected use of energy in locality l is:

$$\begin{aligned} E\left[\mathcal{E}_{lrt} \middle| \mathbf{z}_{lrt}\right] & = \int_{\underline{c}}^{c_{lrt}^*} \frac{1}{\Delta_c} \frac{\gamma k_{lrt}}{h_{lrt}} M_l dc_{lrt} \\ & = \frac{\gamma k_{lrt}}{h_{lrt}} M_l \Pr(c_{lrt} < c_{lrt}^*) \end{aligned} \tag{12}$$

Let us now see how expected energy use in locality l as defined in (12) changes in response to tax policy changes, given the level of physical capital determined in the first stage. The Appendix proves the following:

Proposition 3 *If physical capital is installed in plants according to equation (11), and plants are operated according to equation (8), then: (i)* $\frac{dE[\mathcal{E}_{lrt}|\mathbf{z}_{lrt}]}{d\mu_{lrt}} < 0$*; (ii)* $\frac{dE[\mathcal{E}_{lrt}|\mathbf{z}_{lrt}]}{d\tau_{rt}} > 0$ *if* v_{lrt} *is lower than a cutoff energy price* v^{*}_{lrt}.

An energy tax increase unambiguously lowers the use of energy in the short run. First, an higher price of energy stimulates the use of energy-saving equipment by raising its productivity (equation (6)), thereby curbing energy use. Second, equations (7) and (9) show that the fraction of plants that are operated falls. On the other hand, a shock to τ_{rt} hikes the user cost of capital and depresses the level of energy-saving capital (equation (6)), boosting energy use; however, the plant operation rate diminishes, lowering expected energy use. The former effect dominates if energy prices are low, or net operating income is high. It follows that, conditional on output, *i.e.*, for given plant utilization rate in a locality, energy-saving capital and energy are substitutes. In particular, the short run cross-price Allen elasticity of energy with respect to the user cost of capital (Atkeson and Kehoe, 1999) is:

$$\left.\frac{\frac{dE[\mathcal{E}_{lrt}|\mathbf{z}_{lrt}]}{du_{rt}}}{\frac{E[\mathcal{E}_{lrt}|\mathbf{z}_{lrt}]}{u_{rt}}}\right|_{\substack{dK=0\\ dX=0}} = \frac{1}{2}\psi_{lrt} \tag{13}$$

where $\psi_{lrt} \equiv \frac{h_{lrt}u_{rt}}{v_{lrt}\varepsilon_{lrt}}$ denotes the plant-level cost of energy-saving equipment relative to the cost of energy. If, as in Diaz, Puch and Guillo (2004), we set energy expenditures at 4.6% of GDP and energy-saving capital costs at 4.3% of GDP, we obtain a short run Allen elasticity of energy use with respect to the user cost of capital of 0.467, an almost identical figure as the one estimated by Pindyck and Rotemberg (1983: p. 1074, Table 2, panel A).

3 Empirical analysis: data

I analyze the impact of taxes on the use of factor inputs in Italian localities (provinces and regions), and exploit the changes on firms' fiscal burdens provoked by state-mandated business tax increases in a number of regions. As mentioned above, the major subcentral tax formally falling onto business in Italy is the regional business income tax (*IRAP*, *Imposta Regionale sulle Attività Produttive*). It is an origin based net income-type value added tax paid by all firms, including self-employed activities (Bordignon, Giannini and Panteghini, 2001; Bird, 2003; Keen, 2003). The tax base is calculated annually by a direct subtraction method as the difference between gross receipts (sales revenues) and the cost of intermediate goods and services.[7] Neither labor costs

[7] Specific rules apply to financial intermediaries and insurance companies.

nor debt interest payments are deductible, while conventional tax depreciation provisions apply to outlays for capital goods. The tax is neutral with respect to choice of organizational form, and to equity *versus* debt financing.[8] As for the tax rate, strict limitations on regional rates have existed since its introduction: until 2007, a baseline rate of 4.25% was set nationwide, and regions were allowed to vary it by one percentage point. The central rate was then uniformly reduced to 3.90% in 2008, leaving regions the possibility of increasing or decreasing it by 0.92 percentage points.

The regional business tax was introduced in 1998 to fund health expenditures, the largest outlay in the Italian regions' budgets. Total regional health expenditures surpassed €100 billion in 2006, or around 7% of national GDP and over 80% of total regional spending, with an annual real growth rate systematically exceeding that of GDP in the past two decades. This brought Italy's share of GDP spent on health from significantly below the OECD average in the early 1990s to close to EU countries' average around the mid 2000s (Tediosi, Gabriele and Longo, 2009).[9] While the Italian regions have been in charge of managing and delivering health care services for over thirty years, the issue of the financing of regional health expenditures is still amply debated. During the late 1990s and early 2000s, the own revenue structure of the regions was deeply reformed with the aim of raising the health care budget share to be funded by own revenues and fostering regional government accountability (Bordignon and Turati, 2009; Ferrario and Zanardi, 2011). Moreover, the state and the regions agreed in principle on a system of rewards and sanctions to control excessive increases in expenditures and prevent the creation of budget deficits.

In spite of those efforts, the terms of the financial relationships between state and regional governments remained opaque enough during the early years of the decade as to allow the soft budget constraint problem to explode in the subsequent years. The mounting popular outrage fueled by news of malpractice, fraud and corruption episodes in a number of regions led the newly elected national government in 2006 to mandate increases in regional own tax rates in order to have the burden of fiscal consolidation fall only onto those regions' taxpayers.[10] The regional business income tax rate - an income-type value added tax discussed in more detail below - increased by state command by one percentage point (from the baseline rate of 4.25% to 5.25% of net value added) in six financially distressed regions (table 1). In spite of a nationwide reduction

[8] Moreover, the tax does not discriminate between different sources of equity capital (retained earnings *versus* new subscriptions), and all profits are included in the tax base, irrespective of whether they are retained or distributed. No tax credit is given to shareholders for the tax paid by the company (Bordignon, Giannini and Panteghini, 2001).

[9] In the World Health Organization Report (2000), the Italian health service ranked 2^{nd} among 191 countries with respect to health status, fairness in financial contribution, and responsiveness to people's needs. However, self-reported health conditions, satisfaction with the health care system and popular perception of its quality consistently turned out to be among the lowest in Europe in a number of surveys (Blendon, Kim and Benson, 2001; Maio and Manzoli, 2002).

[10] Total regional debt amounted to over €16 billion in 2005, about half of it being attributable to two regions (Lazio in Central Italy and Campania in Southern Italy).

of the regional business income baseline rate to 3.90% as part of a fiscal stimulus package launched in 2008, mandated rate increases followed in the subsequent years for further regions exhibiting growing deficits.[11] Moreover, the worsening budgetary prospects in four regions induced the state to mandate additional increases in the regional business income tax rate of 0.15% in 2009 and 2010. Overall, as reported in table 1, almost half of the 20 Italian regions were affected by various state-mandated tax increases. The tax hikes led to an average fiscal burden differential for business located in health deficit-running areas of over $\frac{1}{4}$ relative to balanced budget regions.

The empirical strategy of using the regional tax changes provoked by state mandates to estimate the impact of taxes on input use in local production processes relies on the abrupt change in central government policy towards regions that accompanied the widespread government changes that occurred at the 2005 regional elections. This makes the tax mandates exogenous with respect to the evolution of economic conditions across the regions, and in particular with respect to shocks to energy use that might hit the regions during the second half of the 2000s. However, in order to capture the potential effects of other time-varying omitted variables that could be correlated both with the tax mandate decisions and with the province-level variables of interest thus biasing our main results, I control for GDP at the regional level and for the evolution of the demographic size and structure in the energy use determination equation.

In addition to the regional business tax, an excise consumption tax is applied by the lower-level of government - the provinces - on business uses of electricity. The provincial level of government is made of 103 jurisdictions, whose average size roughly corresponds to that of French *Départements*, US counties and UK counties.[12] The provincial tax falls onto all enterprises employing electricity, with the sole exception of massive energy-intensive establishments exceeding kWh 200,000 consumption per month (around fifty times the typical monthly electricity requirement of a small firm). Provincial authorities can set a rate between a statewide lower limit of €9.30 and an upper limit of €11.40 per 1,000 kWh. The limits have remained unchanged in nominal terms through the past decade. Electricity tax revenues make above $\frac{1}{3}$ of provincial own revenues, the rest of provincial expenditures - mostly in the areas of environmental protection and road maintenance - being funded by motor vehicle registration taxes and state grants (Di Porto and Revelli, 2013; Revelli, 2013).

In terms of overall price of electricity, the relatively modest involvement of Italy in European power markets, partly due to limited interconnection capacity, precluded economic efficiency gains and allowed a considerable degree of market concentration during the 2000s (Creti, Fumagalli and Fumagalli, 2010).

[11] One region (Liguria) was allowed to come back to the baseline rate in 2008 thanks to disciplined spending behavior and credible attempts to cut deficit.

[12] Holmes (1998) uses US county manufacturing employment data to test the effect of state policies on the location of business. Devereux, Griffith and Simpson (2007) use plant-level data to study firms' location choices at the level of the UK counties. As argued by Guiso, Sapienza and Zingales (2004) in their analysis of the economic impact of local financial development within an integrated financial market in Italy: "From an economic point of view the natural unit of analysis is the province."

This makes electricity prices in Italy generally higher than EU average for both domestic and business uses, and amongst the highest in Europe as far as small to medium enterprise uses are concerned (European Commission, 2014), with taxes contributing to over one third of the final price of energy (Eurostat, 2014).

I test the effects of the regional business tax and the provincial electricity tax on electricity consumption at the provincial level, that is available by sector of economic activity on an yearly basis for the entire decade $2000-2010$.[13] Energy consumption data come from the holder of the national electricity grid (*TERNA*, *Rete Elettrica Nazionale*). Since I do not have micro-level data on energy use by plants, I investigate the effect of the energy tax both on total business energy consumption in a province, and on business use in the service sector, where average firm size is small and energy consumption is moderate. I also test the effect of the tax on domestic energy consumption, which should be nil given that domestic consumption is exempt from the tax.

I next verify the impact of those taxes on a number of variables measured at the regional level and available from ISTAT, National Statistics Institute, including GDP and employment by sector of economic activity for the period $2000-2009$, and I exploit information from EUROSTAT Statistics on human resources in S&T (science and technology) occupations. Moving to the regional level substantially reduces the number of observations (from over 1,000 to less than 200), but allows me to examine a richer set of indicators of real economic activity. In particular, given the lack of territorial capital stock data, the size of human resources in S&T occupations - and particularly highly skilled human resources that have successfully completed education at the third level in an S&T field of study - can be interpreted as a proxy for energy-saving capital in terms of their contribution to the optimal design and management of production processes. Finally, I use provinces' and regions' resident population size and age structure as controls. Summary statistics are reported in table 2.

4 Estimation results

Tables 3 and 4 report the estimation results on the panel of provinces of the energy use equation:

$$\ln(\mathcal{E}_{lrt}) = \beta_1 \ln(\tau_{rt}) + \beta_2 \ln(\mu_{lrt}) + \ln(\mathbf{z}_{lrt})^{'}\boldsymbol{\gamma} + i_{lr} + y_t + e_{lrt} \tag{14}$$

where I control for nationwide influences on economic activity (such as state corporate tax policy, pre-tax energy price movements, and the business cycle) by including the year dummies y_t. Unobserved time-invariant provincial traits (i_{lr}) are controlled for by demeaning equation (14). The results in table 3 only include the provincial energy excise (μ_{lrt}) and regional business tax rate (τ_{rt}) as

[13] Three regions (two small bilingual regions in the Alps, and the island of Sardinia) and the corresponding seven provinces are excluded from the analysis beacuse of their peculiar institutional status and of substantial changes in their structure of local government during the decade considered here. Further, three provinces involved by boundary changes due to the creation of new local authorities are excluded too. This leaves us with data on 93 provinces.

explanatory variables, while the specifications in table 4 control for an additional set of variables **z** (resident population size, share of elderly population, and GDP measured at the regional level).[14] Reported standard errors in tables 3 and 4 are clustered by region.[15]

The results reveal virtually no impact of the two taxes on total or domestic electricity consumption: the latter turns out to be largely driven by the size of resident population (column (4.2)), with an elasticity of 0.6. On the other hand, the regional business income tax rate has a positive and significant effect (an elasticity of about 0.2) on total business electricity consumption, in particular on the part of it that is used in the service sector (columns (3.5) and (4.5)). The effect on total business electricity is less precisely estimated, though, when GDP is controlled for in table 4: total business electricity consumption increases with GDP with an elasticity of 0.7, and decreases with the share of elderly population with an elasticity of -0.7. Expectedly, the energy tax turns out to have a significant negative effect in the service sector only, where most small and medium-sized firms that are liable to the payment of the tax are found. The result is robust to the inclusion of population size and composition and GDP as controls. The elasticity of electricity consumption in the service sector to the electricity tax is estimated to be around -0.1.

As a robustness check of the above findings, tables 5 and 6 report the estimation results of specifications where the growth rates of energy use in the various sectors are employed as dependent variables, and are regressed on growth rates of the explanatory variables. Table 6 in particular adds one year lags of the energy use determinants. The overall picture is similar to the one emerging from tables 3 and 4, though the energy tax effect vanishes. However, tables 5 and 6 show that GDP and demographic growth turn out to be important determinants of total and business electricity consumption growth, and, most importantly, that the impact of the regional business income tax on energy use in the service sector remains positive and significant.

One might worry at this point that the positive effect of the business income tax on energy use be due to factors other than the mandated tax increases, particularly if the path of energy use consumption in the regions affected by the tax mandates (most of them located in Southern Italy) were significantly different than the path of energy use in unaffected, control regions of Northern Italy. This would create a spurious correlation between the energy use trajectory and the regional tax rates. I have therefore tested the difference in pre-treatment trends (before tax mandates were enacted in 2006) by estimating an energy use equation that allows for a differential trend in 'treated' regions (the regions listed in table 1) versus control regions in the 2000 to 2006 time period. The treated region dummy interacted with the linear time trend variable is never estimated to be significantly different from zero, and the parallel trends hypothesis cannot therefore be rejected. Total and business energy use at the regional level show

[14] The number of observations falls from 1020 in table 3 to 930 in table 4 because GDP is observed until year 2009 only.

[15] Standard errors are virtually identical when employing cluster bootstrapping (Cameron, Gelbach and Miller, 2008).

an annual growth rate of about 2 per cent, the difference between treated and control region over 2000 to 2006 equaling 0.08% (p-value=0.68) and 0.19% (p-value=0.42) for total and business energy use respectively. For energy use in the service sector, the average annual growth rate is almost 6 per cent, the difference between treated and control regions being again positive (0.1%) but far from significant (p-value=0.71).

Table 7 reports instead the results of estimating a dynamic specification, where a lagged dependent variable is included along with lags of the explanatory variables. I estimate the dynamic panel data model by the conventional Arellano and Bond (1991) GMM (generalized method of moments) that transforms the model in first differences to get rid of the province-specific effects i_{lr}, and uses lags of the dependent variable dated $t-2$ and earlier as instruments for the lagged dependent variable. I use up to the $t-5$ lag to build the matrix of instruments. The first and second order serial autocorrelation tests on the first-differenced equation residuals point to the presence of first-order, but not of second-order serial correlation, suggesting that twice lagged values of the dependent variable are valid instruments in the first-differenced equation, while in two of the four equations the Sargan test marginally rejects the hypothesis of instrument orthogonality. Again, the results are generally compatible with the evidence presented above, with GDP playing an important role in explaining energy consumption patterns. The elasticity of energy use with respect to GDP is estimated to be around 0.3, a result that is remarkably robust across the different specifications, and is in line with the recent cross-country empirical evidence (Ozturk, 2010; Belke, Dobnik and Dreger, 2011). As for fiscal policies, the effect of the provincial electricity tax dwindles, while that of the regional business income tax remains fairly strong in the service sector energy use equation.

The above specifications might suffer from an endogeneity problem if provincial authorities anticipate changes in electricity consumption, and manoeuvre their tax rates accordingly. For instance, if they expect energy consumption to decline due, say, to widespread investment in energy-saving technologies or rising energy prices, they might be somewhat mechanically forced to increase the electricity excise tax in order to prevent a tax revenue decline. Table 8 presents GMM estimates of a dynamic panel data specification that allows provincial electricity tax rates to be determined endogenously, adding electricity tax rates lagged $t-2$ to $t-5$ to the instrument matrix. The first and second order serial autocorrelation tests as well as the Sargan test now pass in all equations at conventional confidence levels. However, while the effect of the electricity tax on electricity consumption turns out now to be negative and large in the service sector (but not in the other sectors), it is still imprecisely estimated.

Table 9 reports the fixed effects estimation results on region-level macroeconomic data (GDP and employment). Neither tax is estimated to have a significant impact on GDP (column (9.1)). GDP is estimated to grow with population with an elasticity of about 0.3. In column (9.2), employment in the service sector does indeed rise with GDP and declines when the cost of labor increases due to the mandated tax hike, while the effect of the average provincial energy tax is not significant. Columns (9.3) and (9.4) turn to the type of occupation of human resources. In particular, column (9.3) uses the (log of the) stock of human resources in S&T occupation, independently of workers' education level. Column (9.4) focuses instead on highly skilled human resources (those that have successfully completed education at the third level in an S&T field of study) that are employed in an S&T occupation. This mainly includes professionals and technicians with tertiary education, such as IT system designers, computer programmers, biologists, engineers and economists. In a way, espousing the view of energy-saving capital as a manifestation of human capital in the form of technical skills needed to optimally design and manage a production process, human resources in S&T occupation might be interpretable as a proxy for the stock of energy-saving capital in the regional economy.

The results in table 9 are generally compatible with the theoretical model: the regional business tax is estimated to strongly and significantly depress both indicators of human capital, with the elasticity being slightly larger (over 0.3 in absolute value) for highly skilled workers. On the other hand, average energy taxes in the region turn out to have no effect on human resources in S&T, plausibly due both to the fact that I cannot distinguish here between human resources that are employed by large, energy-intensive firms that are exempt from the provincial electricity tax and those in small and medium enterprises, and to the minor role that is generally played by energy taxation relative to value added taxation in most business sectors.

As a final check on the results obtained on the determinants of electricity use at the provincial level, I estimate equation (14) on the panel of regions. The results are reported in table 10. I use the same electricity aggregates as in tables 3 to 8 and control in addition here for the number of firms. While being potentially endogenous, the number of firms is arguably a non-negligible determinant of the use of energy. In the last column, I restrict the analysis to the eight regions that actually had an increase in the regional business tax. While reducing quite substantially the tax rate variation that can be exploited, any evidence emerging from this restricted sample would strengthen the conclusion that the fiscal impact on energy use is not due in reality to systematic differences between the regions that were affected by the tax mandates and those that were not. Reassuringly, all previous results are confirmed in this region-level analysis, including the one on the restricted sample in column (10.6), with the regional business tax having a positive impact and the average provincial energy tax having a negative impact on energy use in the service sector.

5 Spatial spill-overs

Spatial differences in factor input prices could in principle foster mobility of business activity across provinces, and make economic outcomes and tax bases in a jurisdiction depend on tax policies implemented in other jurisdictions (Brueckner, 2003). Ignoring cross-locality fiscal spillovers when they are actually important might yield biased estimates if decentralized tax policy follows a spatial auto-correlation pattern. If economic activity in province l (X_{lt}) is affected by tax policy in a nearby province j (μ_{jt}) due to tax base mobility, and $cov(\mu_{lt}, \mu_{jt}) \neq 0$, omission of μ_{jt} from the empirical model will cause the estimate of the impact of μ_{lt} on X_{lt} to suffer from a standard omitted variable bias.

In fact, as shown in table 11, the Moran test for spatial dependence reveals some evidence of positive spatial auto-correlation among adjacent provinces' policies in the mid-sample years, while the null hypothesis of random assignment of energy tax rates in space cannot be rejected either in the early sample years, or towards the end of the decade, when most provincial authorities were against the statewide upper tax rate bound.[16] In order to test the relevance of fiscal spillovers, I allow tax policies in neighboring provinces to have an effect on energy use in a province by including a spatially weighted average of electricity tax rates in the other $L-1$ provinces in equation (14):

$$\ln(\mathcal{E}_{lrt}) = \beta_1 \ln(\tau_{rt}) + \beta_2 \ln(\mu_{lrt}) + \beta_3 \ln(\widetilde{\mu}_{lrt}) + \ln(\mathbf{z}_{lrt})' \boldsymbol{\gamma} + i_{lr} + y_t + e_{lrt} \quad (15)$$

where:

$$\widetilde{\mu}_{lrt} = \sum_{j=1}^{L} \omega_{lj} \mu_{jst} \quad (16)$$

In equation (16), $\{\omega_{lj}\} \geq 0$ - with $\omega_{lj} = 0$ if $l = j$ - is a set of non-stochastic weights based on provinces' geographic location, and might equal (or be close to) zero for a non-negligible number of (l, j) pairs (Anselin, 1988).

Similarly, for each region $r = 1, ..., R$ and each year, I build a spatially weighted average of business income tax rates in the other $R-1$ regions:

$$\widetilde{\tau}_{rt} = \sum_{s=1}^{R} \omega_{rs} \tau_{st} \quad (17)$$

where the ω_{rs} weights play a similar role as ω_{lj}. In fact, $\omega_{lj} = \omega_{rs}$ for $l \in r$ and $j \in s$ would imply that all provinces located in a region are exposed to spill-overs of the same intensity from tax policies in nearby regions, irrespective of their own within-region location.

Based on (16) and (17), I experimented with a number of spatial patterns that differ by range and complexity. I report three sets of results in tables 12 to 14 based on fairly standard spatial modelling choices (McMillen, 2010). Table 12 reports the results of a region-level specification that relies on a border-sharing criterion, meaning that $\omega_{rs} = \frac{1}{n_r}$ if regions r and s share a border, with n_r standing for the number of adjacent regions to region r, and $\omega_{rs} = 0$ otherwise. The resulting spatial term in equation (17) is the average business income tax rate in the regions bordering region r.[17] Tables 13 and 14 report the estimation

[16] The Moran statistic equals $(\widetilde{X}'\widetilde{X})^{-1}\widetilde{X}'\mathcal{W}\widetilde{X}$, with $\widetilde{X}$ as the demeaned vector of the variable of interest, and $\mathcal{W}$ a square matrix weighting observation pairs (typically in a binary way) based on their vicinity (Anselin, 1988). In fact, the Moran statistic is the OLS estimate from a regression of a first-order spatial lag of X on X.

[17] Each region has one to four neighbors. The island of Sicily is assumed to have as sole neighbor the region of Calabria, at the extreme south-west of the peninsula.

results of province-level spatial specifications for the use of energy. In table 13, I use a border-sharing criterion, where energy use in a province is allowed to be affected by the average energy tax in adjacent provinces, irrespective of whether those provinces belong to the same or different regions. In table 14, I use instead the average business taxes and average provincial energy taxes in the set of regions bordering the region where a province is located.

The results show no evidence of significant fiscal spillovers in either of those spatial models, suggesting that tax policy changes did not bring about any major shift of production facilities or input use from high-tax to low-tax localities, with factor input adjustments mostly taking place within localities. In fact, due to plant relocation costs, shifting real production across localities in response to tax differentials only tends to be a feasible option for multiplant firms operating establishments in different sites (Markusen, 1995), with smaller-sized local business responding to fiscal shocks in the short run chiefly by manoeuvring their flexible factor input mix.

6 Concluding remarks

This paper has studied theoretically and investigated empirically the effects of state-mandated selective local tax increases on the economy, focusing in particular on the impact of factor input taxes on their use in a decentralized economy. Based on a model of input choice within a multi-jurisdiction neoclassical framework, where production takes place in plants and physical capital requires energy in fixed proportions depending on the size of energy-saving capital that is installed, I have made use of the business tax rate increases that were mandated by the state in the Italian regions with excessive budget deficits around the mid 2000s.

The panel data estimation results shed light on a number of aspects of the interaction between policy choices and local production processes. First, they reveal that mandated regional tax hikes had a significant detrimental impact on employment at the regional level, and particularly on human resources in S&T occupations. An interpretation that is compatible with the theoretical model is that those human resources can be viewed as a proxy for energy-saving capital. Second, those mandated tax increases had a positive impact on province-level business energy use, lending support to the theoretical hypothesis of short run substitution between energy and energy-saving capital. On the other hand, provincial excise taxes on energy are generally found to lessen business consumption of electricity, though the effect is generally small and not always statistically significant, probably due to the minor role played by energy taxation relative to value added taxation in most business sectors. Finally, the estimation of region-level and province-level equations augmented with spatially weighted averages of neighboring regions and provinces' business and energy taxes respectively does not provide any evidence of major shifts of production facilities or variable input use from high-tax to low-tax provinces during the period analyzed here.

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Appendix

Proof of proposition 1

Totally differentiate the first order conditions (4), divide by $d\tau_{rt}$, and rearrange:

$$\begin{aligned}
\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right]\frac{dk_{lrt}}{d\tau_{rt}}+\left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\frac{dh_{lrt}}{d\tau_{rt}}&=\zeta_{rt}\\
\left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\frac{dk_{lrt}}{d\tau_{rt}}-\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\frac{dh_{lrt}}{d\tau_{rt}}&=\zeta_{rt}
\end{aligned}\tag{18}$$

where:

$$\zeta_{rt}\equiv\frac{d}{d\tau_{rt}}\left(\frac{\iota(1-\pi_t)+\delta}{1-\pi_t-\tau_{rt}}\left[1-\delta_0\frac{\pi_t+\tau_{rt}}{\iota(1-\pi_t)+\delta}\right]\right)=\frac{\iota(1-\pi_t)+(\delta-\delta_0)}{\left(1-\pi_t-\tau_{rt}\right)^2}>0$$

Solving system (18) by Cramer's rule:

$$\begin{aligned}
\frac{dk_{lrt}}{d\tau_{rt}}&=\frac{\begin{vmatrix}\zeta_{rt} & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\\ \zeta_{rt} & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}}{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}}\\
&=\zeta_{rt}\frac{-2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}-\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}}{\mathfrak{D}}<0
\end{aligned}\tag{19}$$

$$\begin{aligned}
\frac{dh_{lrt}}{d\tau_{rt}}&=\frac{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \zeta_{rt}\\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & \zeta_{rt}\end{vmatrix}}{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}}\\
&=\zeta_{rt}\frac{(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta-\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}}{\mathfrak{D}}<0
\end{aligned}\tag{20}$$

The determinant $\mathfrak{D}$ in the denominator is positive due to concavity of the profit function (3). This proves parts (i) and (ii) of the proposition. Using (1), (19), and (20), and the fact that $\theta\alpha_l k_{lrt}^{\theta-1}\eta-\left(v+\mu_{lrt}\right)\gamma h_{lrt}^{-1}=\left(v+\mu_{lrt}\right)\gamma k_{lrt}h_{lrt}^{-2}$

from the first order conditions (4), the effect of τ_{rt} on the use of energy is:

$$\begin{aligned}\frac{d\varepsilon_{lrt}}{d\tau_{rt}} &= \frac{\gamma}{h_{lrt}}\left(\frac{dk_{lrt}}{d\tau_{rt}}\right) - \gamma\frac{k_{lrt}}{h_{lrt}^2}\left(\frac{dh_{lrt}}{d\tau_{rt}}\right) \\ &= \zeta_{rt}\frac{\gamma^2}{h_{lrt}\mathfrak{D}}\left(-\theta^2\alpha_l k_{lrt}^{\theta-1}\eta\right) < 0\end{aligned} \tag{21}$$

Proof of proposition 2

Totally differentiate the first order conditions (4), divide by $d\mu_{lrt}$, and rearrange:

$$\begin{aligned}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right]\frac{dk_{lrt}}{d\mu_{lrt}} + \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\frac{dh_{lrt}}{d\mu_{lrt}} &= \frac{\gamma}{h_{lrt}} \\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right]\frac{dk_{lrt}}{d\mu_{lrt}} - \left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\frac{dh_{lrt}}{d\mu_{lrt}} &= -\frac{\gamma k_{lrt}}{h_{lrt}^2}\end{aligned} \tag{22}$$

Solving system (22) by Cramer's rule:

$$\begin{aligned}\frac{dk_{lrt}}{d\mu_{lrt}} &= \frac{\begin{vmatrix}\frac{\gamma}{h_{lrt}} & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] \\ -\frac{\gamma k_{lrt}}{h_{lrt}^2} & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}}{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] \\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}} \\ &= -\frac{\frac{\gamma k_{lrt}}{h_{lrt}^2}\left(\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right)}{\mathfrak{D}} < 0\end{aligned} \tag{23}$$

$$\begin{aligned}\frac{dh_{lrt}}{d\mu_{lrt}} &= \frac{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \frac{\gamma}{h_{lrt}} \\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & -\frac{\gamma k_{lrt}}{h_{lrt}^2}\end{vmatrix}}{\begin{vmatrix}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-2}\eta\right] & \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] \\ \left[\gamma\frac{v+\mu_{lrt}}{h_{lrt}^2}\right] & -\left[2\left(v+\mu_{lrt}\right)\frac{\gamma k_{lrt}}{h_{lrt}^3}\right]\end{vmatrix}} \\ &= -\frac{\frac{\gamma}{h_{lrt}^2}\left[(\theta-1)\theta\alpha_l k_{lrt}^{\theta-1}\eta + \gamma\frac{v+\mu_{lrt}}{h_{lrt}}\right]}{\mathfrak{D}} \\ &= -\frac{1}{\mathfrak{D}}\frac{\gamma^2\left(v+\mu_{lrt}\right)}{h_{lrt}^3}\left[(\theta-1)\frac{k_{lrt}}{h_{lrt}} + \theta\right] \\ &\gtreqless 0 \iff \frac{k_{lrt}}{h_{lrt}} \gtreqless \frac{\theta}{1-\theta}\end{aligned} \tag{24}$$

where I have used $\theta\alpha_l k_{lrt}^{\theta-1}\eta = (v+\mu_{lrt})\gamma h_{lrt}^{-1}(1+k_{lrt}h_{lrt}^{-1})$ from (4). Finally, the effect of the excise tax on the use of energy is:

$$\begin{aligned}\frac{d\varepsilon_{lrt}}{d\mu_{lrt}} &= \frac{\gamma}{h_{lrt}}\left(\frac{dk_{lrt}}{d\mu_{lrt}}\right) - \gamma\frac{k_{lrt}}{h_{lrt}^2}\left(\frac{dh_{lrt}}{d\mu_{lrt}}\right) \\ &= \frac{\gamma^2}{h_{lrt}^3\mathfrak{D}}(\theta-1)\theta\alpha_l k_{lrt}^{\theta}\eta < 0\end{aligned} \tag{25}$$

Proof of proposition 3

Derive equation (12) with respect to μ_{lrt}:

$$\begin{aligned}&\frac{dE\left[\mathcal{E}_{lrt}|\,\mathbf{z}_{lrt}\right]}{d\mu_{lrt}} \\ &= \frac{M_l}{\Delta_c}\left\{-\gamma\frac{k_{lrt}}{h_{lrt}^2}\Pr(c_{lrt}<c_{lrt}^*) + \gamma\frac{k_{lrt}}{h_{lrt}}\left[v_{lrt}\frac{\gamma k_{lrt}}{h_{lrt}^2} - u_{rt}\right]\right\}\frac{dh_{lrt}}{d\mu_{lrt}} \\ &+ \frac{M_l}{\Delta_c}\gamma\frac{k_{lrt}}{h_{lrt}}\left(\frac{d\Pr(c_{lrt}<c_{lrt}^*)}{d\mu_{lrt}}\right)\end{aligned} \tag{26}$$

Using (6), and totally differentiating it to obtain $\frac{dh_{lrt}}{d\mu_{lrt}}$:

$$\frac{dE\left[\mathcal{E}_{lrt}|\,\mathbf{z}_{lrt}\right]}{d\mu_{lrt}} = -\frac{M_l}{\Delta_c}\frac{\gamma k_{lrt}}{h_{lrt}^2}\left\{\frac{h_{lrt}}{2v_{lrt}}\Pr(c_{lrt}<c_{lrt}^*) + k_{lrt}\right\} < 0 \tag{27}$$

Next derive equation (12) with respect to τ_{rt}. Using (6), and with $\iota_t = \iota(1-\pi_t)+(\delta-\delta_0)$:

$$\begin{aligned}&\frac{dE\left[\mathcal{E}_{lrt}|\,\mathbf{z}_{lrt}\right]}{d\tau_{rt}} \\ &= \frac{M_l}{\Delta_c}\left\{-\gamma\frac{k_{lrt}}{h_{lrt}^2}\Pr(c_{lrt}<c_{lrt}^*)\right\}\frac{dh_{lrt}}{d\tau_{rt}} \\ &+ \frac{M_l}{\Delta_c}\gamma\frac{k_{lrt}}{h_{lrt}}\left(\frac{d\Pr(c_{lrt}<c_{lrt}^*)}{d\tau_{rt}}\right) \\ &= \frac{M_l}{\Delta_c}\left\{-\gamma\frac{k_{lrt}}{h_{lrt}^2}\Pr(c_{lrt}<c_{lrt}^*)\right\}\left(-\frac{h_{lrt}^3}{2v_{lrt}k_{lrt}}\frac{\iota_t}{(1-\pi_t-\tau_{rt})^2}\right) \\ &- \frac{M_l}{\Delta_c}\gamma\frac{k_{lrt}}{h_{lrt}}\left[\frac{\eta\lambda_{rt}}{1-\pi_t-\tau_{rt}} + h_{lrt}\frac{\iota_t}{(1-\pi_t-\tau_{rt})^2}\right] \\ &= \frac{M_l}{\Delta_c}\frac{\iota_t\frac{h_{lrt}}{2v_{lrt}}\Pr(c_{lrt}<c_{lrt}^*) - \frac{\gamma k_{lrt}}{h_{lrt}}\left(\eta\lambda_{rt}\left(1-\pi_t-\tau_{rt}\right)+\iota_t h_{lrt}\right)}{(1-\pi_t-\tau_{rt})^2} \\ &\gtrless 0 \iff v_{lrt} \lesseqgtr v_{lrt}^* \equiv \frac{\alpha_l k_{lrt}^{\theta}\eta - \eta\lambda_{rt} - h_{lrt}u_{rt} - \underline{c}}{\frac{\gamma k_{lrt}}{h_{lrt}}\left(2\frac{\eta\lambda_{rt}(1-\pi_t-\tau_{rt})+\iota_t h_{lrt}}{\iota_t h_{lrt}}+1\right)}\end{aligned} \tag{28}$$

Table 1

Mandated (*) regional business income tax rates (%)

region	2006	2007	2008	2009	2010
Abruzzo	4.25	5.25*	4.82*	4.82*	4.82*
Calabria	4.25	4.25	3.90	4.82*	4.97*
Campania	4.55*	5.25*	4.82*	4.97*	4.97*
Lazio	4.25	5.25*	4.82*	4.82*	4.97*
Liguria	4.25	5.25*	3.90	3.90	3.90
Molise	4.25	5.25*	4.82*	4.82*	4.97*
Puglia	4.25	4.25	4.82*	4.82*	4.82*
Sicilia	4.25	5.25*	4.82*	4.82*	4.82*
baseline rate	4.25	4.25	3.90	3.90	3.90

Notes: the remaining 12 regions suffered no state-mandated rate increase. The Liguria region was freed from the mandated rate increase after 2007.

Table 2
Descriptive statistics

	mean	s.d.	min	max	source
provinces (1,020 observations)					
electricity use (GWh=1,000 MWh)					TERNA Rete Elettrica
- total	2,904.8	3,035.3	323.8	21,976.8	
- domestic	646.4	774.8	75.9	5,687.4	
- business	2,258.4	2,377.8	171.5	16,959.5	
- services	583.7	928.7	38.2	7848.5	
electricity rate (€/MWh)	10.5	0.9	9.3	11.4	Italian Government
population (,000)	583.1	645.2	88.7	4194.0	ISTAT
elderly population (%)	20.7	2.9	12.3	27.9	ISTAT
regions (170 observations)					
GDP (€ billion)	69.3	61.2	0.5	268.6	ISTAT
population (,000)	3,282.1	2,350.3	320.0	9,826.1	ISTAT
elderly population (%)	20.7	2.6	15.8	26.7	ISTAT
tertiary employment (,000)	810.4	618.5	63.6	2728.8	EUROSTAT
human resources in S&T	370.3	311.1	27.1	1491.0	EUROSTAT
skilled human res. in S&T	143.2	115.8	10.0	566.1	EUROSTAT
business income tax rate	4.33	0.3	3.9	5.25	Italian Government

Table 3
Province-level electricity use

	Electricity use				
	total	domestic	business	non-service	services
	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)
τ_{rt}	0.116	-0.007	0.182**	0.122	0.178**
(regional business tax)	(0.071)	(0.043)	(0.085)	(0.094)	(0.069)
μ_{lrt}	0.015	0.010	0.008	-0.003	-0.113**
(provincial energy tax)	(0.055)	(0.024)	(0.067)	(0.089)	(0.051)
obs.	1020	1020	1020	1020	1020

Notes: all variables in logs; year effects and locality fixed effects included; standard errors clustered by region in brackets below the coefficients; ***,** ,*: p-value $<$ 0.01, 0.05, 0.10.

Table 4
Province-level electricity use (constant output)

	Electricity use				
	total	domestic	business	non-service	services
	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)
τ_{rt}	0.153*	0.042	0.200*	0.157	0.185***
(regional business tax)	(0.084)	(0.041)	(0.106)	(0.119)	(0.066)
μ_{lrt}	0.021	0.031	0.007	-0.003	-0.106**
(provincial energy tax)	(0.053)	(0.019)	(0.069)	(0.088)	(0.045)
population	0.475	0.601***	0.348	0.441	-0.219
	(0.425)	(0.185)	(0.540)	(0.590)	(0.359)
elderly share	-0.518**	0.171**	-0.657**	-0.830**	-0.159
	(0.322)	(0.071)	(0.247)	(0.304)	(0.250)
GDP	0.511	0.045	0.689*	0.886*	-0.322
	(0.325)	(0.130)	(0.403)	(0.454)	(0.218)
obs.	930	930	930	930	930

Notes: see table 3.

Table 5
Province-level electricity use growth

	Electricity use				
	total	domestic	business	non-service	services
	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)
τ_{rt}	0.021	-0.024	0.031	-0.006	0.059**
	(0.031)	(0.024)	(0.037)	(0.049)	(0.024)
μ_{lrt}	0.006	0.034*	-0.006	-0.011	-0.001
	(0.024)	(0.019)	(0.034)	(0.045)	(0.019)
population	0.181	0.256	0.082	0.120	-0.102
	(0.314)	(0.289)	(0.445)	(0.479)	(0.229)
elderly share	-0.517***	0.211	-0.666***	-0.854***	-0.108
	(0.140)	(0.135)	(0.202)	(0.266)	(0.196)
GDP	0.306***	-0.071	0.377***	0.564**	-0.193
	(0.111)	(0.058)	(0.144)	(0.210)	(0.137)
obs.	837	837	837	837	837

Notes: all variables in log(difference); one cross-section is lost in building growth rates; year effects included; standard errors clustered by region in brackets below the coefficients; ***,** ,*: p-value $<$ 0.01, 0.05, 0.10.

Table 6
Province-level electricity use growth (lagged controls)

	Electricity use				
	total	domestic	business	non-service	services
	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)
τ_{rt}	0.032	-0.021	0.047	0.009	0.073***
	(0.031)	(0.026)	(0.037)	(0.050)	(0.025)
τ_{rt-1}	-0.008	-0.007	-0.005	-0.010	0.040
	(0.037)	(0.025)	(0.049)	(0.056)	(0.041)
μ_{lrt}	-0.006	0.042*	-0.028	-0.046	0.014
	(0.031)	(0.023)	(0.043)	(0.058)	(0.029)
μ_{lrt-1}	-0.015	-0.013	-0.017	-0.032	-0.008
	(0.029)	(0.023)	(0.039)	(0.047)	(0.027)
population	0.115	0.065	0.081	0.093	-0.108
	(0.295)	(0.407)	(0.400)	(0.520)	(0.319)
population$_{t-1}$	0.137	0.213	0.096	0.170	0.012
	(0.304)	(0.244)	(0.350)	(0.495)	(0.192)
elderly share	-0.412	0.481*	-0.719**	-1.040**	0.035
	(0.292)	(0.276)	(0.371)	(0.471)	(0.327)
elderly share$_{t-1}$	-0.184	-0.268	-0.019	0.173	-0.217
	(0.332)	(0.261)	(0.413)	(0.519)	(0.375)
GDP	0.330**	-0.024	0.363**	0.568**	-0.210
	(0.136)	(0.079)	(0.166)	(0.245)	(0.145)
GDP$_{t-1}$	0.235*	0.145	0.315*	0.312*	0.190
	(0.136)	(0.076)	(0.167)	(0.169)	(0.210)
	Long-term coefficients				
τ	0.024	-0.028	0.042	-0.001	0.113**
	(0.052)	(0.041)	(0.066)	(0.077)	(0.047)
μ	-0.021	0.029*	-0.045	-0.078	0.006
	(0.047)	(0.018)	(0.061)	(0.078)	(0.034)
obs.	744	744	744	744	744

Notes: see table 5.

Table 7
Dynamic province-level electricity use

	Electricity use				
	total	domestic	business	non-service	services
	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)
$\mathcal{E}_{lrt-1}$	0.750***	0.026	0.836***	0.802***	0.458***
	(0.179)	(0.061)	(0.127)	(0.144)	(0.115)
τ_{rt}	0.018	-0.034	0.016	-0.011	0.073***
	(0.033)	(0.030)	(0.044)	(0.054)	(0.028)
τ_{rt-1}	-0.015	-0.017	-0.025	-0.004	-0.007
	(0.042)	(0.019)	(0.048)	(0.059)	(0.037)
μ_{lrt}	0.001	0.040	-0.020	-0.050	0.017
	(0.032)	(0.021)	(0.044)	(0.052)	(0.030)
μ_{lrt-1}	-0.016	-0.014	-0.014	-0.022	-0.022
	(0.028)	(0.021)	(0.038)	(0.047)	(0.036)
population	0.008	-0.001	0.251	0.045	-0.080
	(0.303)	(0.299)	(0.451)	(0.622)	(0.364)
population$_{t-1}$	0.129	0.281	-0.104	0.116	-0.164
	(0.341)	(0.202)	(0.460)	(0.654)	(0.340)
elderly share	0.050	0.477*	-0.262	-0.529	-0.248
	(0.309)	(0.259)	(0.412)	(0.538)	(0.410)
elderly share$_{t-1}$	-0.249	-0.329	-0.001	0.269	-0.144
	(0.375)	(0.232)	(0.482)	(0.590)	(0.361)
GDP	0.313***	-0.048	0.321*	0.562**	-0.211
	(0.130)	(0.083)	(0.175)	(0.231)	(0.146)
GDP$_{t-1}$	0.118	0.230*	0.060	-0.085	0.308
	(0.148)	(0.123)	(0.203)	(0.243)	(0.205)
	Long-term coefficients				
τ	0.013	-0.052	-0.057	-0.073	0.122
	(0.189)	(0.045)	(0.315)	(0.308)	(0.078)
μ	-0.063	0.028	-0.209	-0.363	-0.010
	(0.143)	(0.018)	(0.300)	(0.365)	(0.067)
AR(1) test (p value)	-3.27 (0.00)	-1.60 (0.10)	-4.27 (0.00)	-3.97 (0.00)	-4.21 (0.00)
AR(2) test (p value)	-0.38 (0.70)	0.10 (0.92)	-0.11 (0.92)	-0.21 (0.83)	-0.80 (0.43)
Sargan test (p value)	37.12 (0.14)	50.44 (0.01)	30.57 (0.39)	28.08 (0.51)	46.39 (0.02)
obs.	744	744	744	744	744

Notes: Arellano and Bond (1991) generalized method of moments estimator; first step results; robust standard errors in brackets; instruments used until lag t-5; AR(1) and AR(2) are tests for first and second order serial correlation respectively, and are distributed as standard normal; the Sargan test is distributed as χ^2 with 29 degrees of freedom (number of overidentifying restrictions); ***,** ,*: p-value $<$ 0.01, 0.05, 0.10.

Table 8
Dynamic province-level electricity use (endogenous electricity tax)

	Electricity use				
	total	domestic	business	non-service	services
	(8.1)	(8.2)	(8.3)	(8.4)	(8.5)
$\mathcal{E}_{lrt-1}$	0.717***	0.028	0.811***	0.802***	0.356***
	(0.143)	(0.067)	(0.104)	(0.120)	(0.109)
τ_{rt}	0.018	-0.035	0.021	-0.012	0.078***
	(0.030)	(0.031)	(0.039)	(0.048)	(0.032)
τ_{rt-1}	-0.006	-0.016	-0.013	0.007	0.009
	(0.042)	(0.020)	(0.049)	(0.060)	(0.037)
μ_{lrt}	0.016	-0.034	0.030	0.001	-0.250
	(0.084)	(0.070)	(0.115)	(0.147)	(0.156)
μ_{lrt-1}	0.038	0.016	0.057	0.067	0.111
	(0.086)	(0.054)	(0.105)	(0.121)	(0.144)
population	-0.026	-0.014	0.190	-0.025	-0.371
	(0.268)	(0.294)	(0.434)	(0.604)	(0.378)
population$_{t-1}$	0.208	0.271	0.024	0.272	-0.011
	(0.303)	(0.206)	(0.429)	(0.613)	(0.361)
elderly share	0.013	0.471*	-0.289	-0.498	-0.285
	(0.308)	(0.259)	(0.412)	(0.542)	(0.425)
elderly share$_{t-1}$	-0.232	-0.324	0.015	0.241	-0.090
	(0.378)	(0.239)	(0.481)	(0.584)	(0.355)
GDP	0.342***	-0.061	0.351**	0.594**	-0.228
	(0.132)	(0.091)	(0.179)	(0.236)	(0.159)
GDP$_{t-1}$	0.143	0.212*	0.111	-0.063	0.321
	(0.139)	(0.126)	(0.189)	(0.217)	(0.221)
	Long-term coefficients				
τ	0.041	-0.053	0.042	-0.025	0.136**
	(0.171)	(0.048)	(0.271)	(0.285)	(0.067)
μ	0.189	-0.018	0.459	0.342	-0.216*
	(0.191)	(0.052)	(0.413)	(0.494)	(0.127)
AR(1) test (p value)	-3.65 (0.00)	-1.68 (0.09)	-4.58 (0.00)	-4.36 (0.00)	-3.35 (0.00)
AR(2) test (p value)	-0.41 (0.68)	0.21 (0.83)	-0.18 (0.86)	-0.29 (0.77)	-1.38 (0.17)
Sargan test (p value)	64.77 (0.11)	69.26 (0.06)	57.34 (0.28)	55.41 (0.35)	54.14 (0.39)
obs.	744	744	744	744	744

Notes: Arellano and Bond (1991) generalized method of moments estimator; first step results; robust standard errors in brackets; instruments used until lag t-5; AR(1) and AR(2) are tests for first and second order serial correlation respectively, and are distributed as standard normal; the Sargan test is distributed as χ^2 with 52 degrees of freedom (number of overidentifying restrictions); ***,** ,*: p-value < 0.01, 0.05, 0.10.

Table 9
Region-level economic indicators

	GDP	tertiary employment	human resources in S&T total	human resources in S&T highly skilled
	(9.1)	(9.2)	(9.3)	(9.4)
τ_{rt}	0.021	-0.104***	-0.276***	-0.316***
	(0.020)	(0.037)	(0.077)	(0.117)
μ_{lrt}	-0.020	0.002	0.163	0.011
	(0.040)	(0.072)	(0.149)	(0.228)
population	0.317***	0.103	0.673**	-0.310
	(0.087)	(0.165)	(0.341)	(0.521)
elderly share	-0.143	-0.158	-0.503	-1.216**
	(0.095)	(0.174)	(0.359)	(0.549)
GDP		0.349**	0.212	-0.059
		(0.153)	(0.316)	(0.483)
obs.	170	170	170	170

Notes: all variables in logs; year effects and region fixed effects included; ***,** ,*: p-value $<$ 0.01, 0.05, 0.10.

Table 10
Region-level electricity use

	Electricity use					
	total	domestic	business	non-service	services	services
	(10.1)	(10.2)	(10.3)	(10.4)	(10.5)	(10.6)
τ_{rt}	0.067*	0.003	0.090*	0.009	0.100**	0.228***
	(0.040)	(0.027)	(0.051)	(0.055)	(0.047)	(0.087)
μ_{lrt}	-0.011	-0.056	-0.026	0.004	-0.378**	-0.754**
	(0.078)	(0.052)	(0.099)	(0.106)	(0.091)	(0.152)
population	-0.228	0.371***	-0.371	-0.427	-0.409	-0.872*
	(0.199)	(0.133)	(0.253)	(0.273)	(0.235)	(0.442)
elderly	0.301	0.305*	0.385	0.424	0.071	0.696*
	(0.195)	(0.130)	(0.248)	(0.268)	(0.230)	(0.378)
GDP	0.417**	0.037	0.477**	0.617***	-0.457**	-0.222
	(0.166)	(0.110)	(0.211)	(0.227)	(0.196)	(0.278)
firms	0.071	0.113*	0.072	0.076	0.237***	0.122
	(0.074)	(0.050)	(0.094)	(0.101)	(0.087)	(0.166)
obs.	170	170	170	170	170	80

Notes: all variables in logs; year effects (2000 to 2009) and region fixed effects included; column (10.6) includes only the 8 regions having a business tax increase over the decade; ***,** ,*: p-value $< 0.01, 0.05, 0.10$.

Table 11
Moran test on provincial electricity tax rates

	Moran test (p value)
2000	0.03 (0.54)
2001	0.06 (0.31)
2002	0.09 (0.14)
2003	0.12 (0.07)
2004	0.10 (0.15)
2005	0.17 (0.02)
2006	0.18 (0.01)
2007	0.13 (0.05)
2008	0.05 (0.38)
2009	0.05 (0.38)

Notes: 93 provincial electricity tax rates in each cross-section; the Moran statistic is asymptotically normally distributed.

Table 12
Spatial spill-overs: regions (border sharing)

	GDP	tertiary employment	human resources in S&T total	human resources in S&T highly skilled
	(12.1)	(12.2)	(12.3)	(12.4)
τ_{rt}	0.021	-0.126***	-0.236***	-0.335***
	(0.022)	(0.040)	(0.083)	(0.127)
μ_{lrt}	-0.020	0.022	0.126	0.028
	(0.041)	(0.073)	(0.152)	(0.233)
$\widetilde{\tau}_{rt}$	0.001	0.089	-0.166	0.080
	(0.035)	(0.063)	(0.130)	(0.200)
population	0.318***	0.176	0.538	-0.244
	(0.092)	(0.172)	(0.356)	(0.548)
elderly share	-0.143	-0.118	-0.577	-1.180**
	(0.097)	(0.175)	(0.363)	(0.558)
GDP		0.348**	0.213	-0.059
		(0.152)	(0.316)	(0.484)
obs.	170	170	170	170

Notes: see table 9.

Table 13
Spatial spill-overs: provinces (border-sharing)

	Electricity use		
	total	business	services
	(13.1)	(13.2)	(13.3)
τ_{rt}	0.156*	0.205*	0.180***
	(0.084)	(0.105)	(0.065)
μ_{lrt}	0.118	0.003	-0.102**
	(0.052)	(0.068)	(0.048)
$\widetilde{\mu}_{lrt}$	0.066	0.091	-0.085
	(0.106)	(0.134)	(0.112)
population	0.486	0.364	-0.234
	(0.439)	(0.558)	(0.349)
elderly share	-0.521**	-0.662**	-0.155
	(0.196)	(0.248)	(0.257)
GDP	0.498	0.670*	-0.305
	(0.314)	(0.390)	(0.222)
obs.	930	930	930

Notes: see table 3.

Table 14
Spatial spill-overs: provinces (cross-region)

	Electricity use		
	total	business	services
	(14.1)	(14.2)	(14.3)
τ_{rt}	0.135*	0.193**	0.138**
	(0.067)	(0.084)	(0.056)
μ_{lrt}	0.040	0.031	-0.089*
	(0.044)	(0.057)	(0.048)
$\widetilde{\tau}_{rt}$	0.151	0.155	0.212
	(0.096)	(0.125)	(0.127)
$\widetilde{\mu}_{lrt}$	0.195	0.291	0.093
	(0.298)	(0.404)	(0.286)
population	0.541	0.425	-0.146
	(0.392)	(0.494)	(0.362)
elderly share	-0.512**	-0.658**	-0.134
	(0.185)	(0.238)	(0.253)
GDP	0.446	0.402	-0.394
	(0.323)	(0.390)	(0.208)
obs.	930	930	930

Notes: see table 3.